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Prognostic Value of Usual Gait Speed in Well-Functioning Older People—Results from the Health, Aging and Body Composition Study

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OBJECTIVES: To define clinically relevant cutpoints for usual gait speed and to investigate their predictive value for health-related events in older persons.

DESIGN: Prospective cohort study.

SETTING: Health, Aging and Body Composition Study.

PARTICIPANTS: Three thousand forty-seven well-functioning older persons (mean age 74.2).

MEASUREMENTS: Usual gait speed on a 6-m course was assessed at baseline. Participants were randomly divided into two groups to identify (Sample A; n = 2,031) and then validate (Sample B; n = 1,016) usual gait-speed cutpoints. Rates of persistent lower extremity limitation events (mean follow-up 4.9 years) were calculated according to gait speed in Sample A. A cutpoint (defining high- (<1 m/s) and low risk (≥ 1 m/s) groups) was identified based on persistent lower extremity limitation events. The predictive value of the identified cutpoints for major health-related events (persistent severe lower extremity limitation, death, and hospitalization) was evaluated in Sample B using Cox regression analyses.

RESULTS: A graded response was seen between risk groups and health-related outcomes. Participants in the high-risk group had a higher risk of persistent lower extremity limitation (rate ratio (RR) = 2.20, 95% confidence interval (CI) = 1.76–2.74), persistent severe lower extremity limitation (RR = 2.29, 95% CI = 1.63–3.20), death (RR = 1.64, 95% CI = 1.14–2.37), and hospitalization (RR = 1.48, 95% CI = 1.02–2.13) than those in the low-risk group.

CONCLUSION: Usual gait speed of less than 1 m/s identifies persons at high risk of health-related outcomes in well-functioning older people. Provision of a clinically meaningful cutpoint for usual gait speed may facilitate its use in clinical and research settings. **J Am Geriatr Soc 53:1675–1680, 2005.**

Key words: physical performance; gait speed; lower extremity limitation; death; hospitalization

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Clinicians have not widely adopted the use of performance-based measures to evaluate the functional status of older persons, possibly owing to the perception that these tests often require substantial space or special equipment or are unduly time consuming.[1,2] Moreover, previously defined cutpoints for physical performance measures, derived from distributions in specific populations,[2–8] might have limited applicability to the general population. Furthermore, the normal values of these measures remain undefined, which makes their clinical application difficult. A cutpoint indicating normal values has crucial importance in promoting the use of continuous markers in the clinical setting.

Of the available physical performance measures, usual gait speed may represent the one that is most suitable to be implemented in the standard clinical evaluation of older persons. Usual gait speed is a quick, inexpensive, and highly

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reliable measure of functional capacity that can be easily measured in the clinical setting.[9] Moreover, its well-documented predictive value for major health-related outcomes[10–12] makes it a useful screening tool to identify older persons at risk of events.

The purpose of the present study was to determine a cutpoint value for usual gait speed over a short (6-m) course using the Health, Aging and Body Composition Study (Health ABC) cohort. Because Health ABC enrolled a large sample of only well-functioning nondisabled older persons, it affords an excellent opportunity to establish the prognostic value of physical performance in older people and to provide an estimate of their normal values.

METHODS

Data are from Health ABC, a prospective cohort study investigating the effect of changes in body composition and health conditions on physiological and functional status at increased age. Participants (N = 3,075) were recruited between April 1997 and June 1998 from a list of Medicare beneficiaries residing in the areas surrounding Pittsburgh, Pennsylvania, and Memphis, Tennessee. Eligibility criteria were no reported difficulty walking one-quarter of a mile, climbing 10 steps, or performing basic activities of daily living; no life-threatening illness; and no plans to leave the area for 3 years.

The present study is based on 3,047 participants; 28 participants with missing data on gait speed or outcome variables were excluded. All participants provided written informed consent. The institutional review boards of the clinical sites approved the study protocol.

Usual Gait Speed Assessment

At the baseline clinic assessment, participants were instructed to stand still with their feet behind and just touching a starting line marked with tape and then to walk at their normal pace along a 6-m course until a few steps past the finish line after the examiner's command of "Go." Timing was started with the first footfall and stopped with the participant's first footfall after crossing the 6-m end line. The fastest time of two trials (in m/s) was used for the present analyses.[13]

Outcomes

All study participants had annual clinical visits and interim 6-month telephone contacts during which health status was assessed and information on interim hospitalizations and major outpatient procedures was collected. When an overnight hospitalization or major outpatient procedure was reported, hospital records were obtained and a Health ABC disease adjudicator at each site verified the event.

For the present analyses, walking speed has been related to the following outcomes.

1. Primary outcome: persistent lower extremity limitation (two consecutive semiannual self-reports of having any difficulty walking one-quarter of a mile or climbing up 10 steps without resting).
2. Secondary outcomes:
   - persistent severe lower extremity limitation (two consecutive self-reports of having a lot of difficulty or not being able to walk one-quarter of a mile or to climb up 10 steps without resting).
   - death (date obtained from the death certificate).
   - hospitalization (any overnight hospitalization in an acute care setting during the first year of follow-up).

Usual Gait-Speed Cutpoints

A gait-speed cutpoint was identified on the basis of the rates of incident persistent lower extremity limitation events (over 5 years of follow-up) in a randomly chosen subsample of the Health ABC participants (Sample A) constituting two-thirds of the overall participants (n = 2,031). It was decided to base the identification of the usual gait-speed cutpoint on the onset of persistent lower extremity limitation (primary outcome) because of the well-demonstrated association between walking speed and incident functional limitation.[3,4,9] Moreover, persistent lower extremity limitation is a particularly important outcome in geriatrics because it not only predicts severe health-related outcomes,[10–12] but also tends to occur early in the disabling process[14] and therefore may be amenable to interventions. Event rates were calculated per 100 participant-years for categories of increasing usual gait speed (category width = 0.05 m/s) in Sample A. After visual inspection of the graph, a cutpoint defining high- and low-risk groups based on persistent lower extremity limitation event rates was assigned. The remaining one-third of the overall participants (Sample B, n = 1,016) was then used to evaluate the predictive value of the identified cutpoint for major health-related events.

Statistical approaches different from the one chosen are also available to define cutpoints for a continuous variable, such as receiver operating characteristic (ROC) curves, classification and regression tree (CART) analyses, the fitting of spline curves (or other nonlinear functions) to identify inflection points in the risk function, and using cutpoints derived from the quantile distribution of the predictor. The use of ROC curves is not necessarily optimal for clinical use to predict future risk. For screening, specificity is considered more important than sensitivity, and the use of a too-sensitive cutpoint can lead to the examination of an unacceptable number of false-positive cases. Similar to ROC curves, CART analyses will lead to results of difficult implementation in the standard clinical evaluation of older persons. Moreover, the algorithm design drives CART analyses, and according to the different options included in the models, different results are obtained. The use of splines or other nonlinear response functions was not helpful in this instance because there was no evidence of a discontinuity in the relationship between walking speed and future event using the Cox proportional hazards model. The categorization of usual gait speed in percentiles is often used, but the applicability of cutpoints based on these results is then tied to the particular population from which they were derived.

The analytical approach used in this study to categorize usual gait speed may lead to the identification of an "arbitrarily" chosen cutpoint. This approach is needed to identify cutpoints for biological markers, implying a continuous gradient of risk in which it is not possible to statistically derive an optimal and unique cutpoint.

Covariates

Covariates included sociodemographic factors (age, sex, race, study site, smoking, alcohol consumption, education), health indicators (body mass index (body weight/height^2)), Modified Mini-Mental State Examination score,[15] and physical activity (calculated based on the Harvard Alumni Study[16] variable based on walking and exercise expenditure in kcal/wk), and clinical conditions (coronary heart disease, diabetes mellitus, hypertension, osteoarthritis, peripheral artery disease, cerebrovascular disease, depression, and pulmonary disease, as defined by algorithms identified by Health ABC clinical investigators[17]).

Statistical Analyses

A usual-gait-speed cutpoint was defined by inspecting the graphical distribution of the event rates per 100 participant-years according to walking speed in a randomly selected subset of participants (Sample A). The predictive value for study outcomes of the identified usual-gait-speed cutpoint was then validated in the remaining one-third (Sample B). Differences in proportions and means of covariates across low- and high-risk groups were assessed in Sample B using chi-square and analysis of variance statistics, respectively. Positive and negative likelihood ratios and 95% confidence intervals (CIs) were calculated for usual gait speed at various cutpoints in Sample B. Cox proportional hazards analyses were performed to assess the relative risk of incident events according to the designated gait-speed cutpoint, treating the low-risk group as the reference. Rate ratios (RRs) and 95% CIs were adjusted for age, sex, race, and all other covariates with a significant ($P<.10$) association with walking speed in univariate analyses.

For the persistent (severe) lower extremity limitation outcome, the days to event were determined from the baseline assessment visit date to the date of the first of two successive reports of difficulty. For participants who did not develop functional limitation, follow-up time was censored to the last contact or date of death. For the mortality outcome, the days to event were determined from the baseline visit date to the date of death. For the hospitalization outcome, the follow-up time was defined as the time from the baseline visit to the first hospitalization date (for those who had one). For those who had no hospitalization event during the first year of follow-up, time was censored at 1 year of follow-up or death date (if it occurred within the first year).

RESULTS

Mean age ± standard deviation of the overall sample (N = 3,047; 51.5% women, 58.5% white) was 74.2 ± 2.9. About 10% of participants were current smokers. One-quarter of the sample had a body mass index higher than 30 kg/m^2, whereas 14.7% reported weekly energy expenditure in physical activity of higher than 2,000 kcal. Of the overall sample, 19.9% had a score lower than 85 on the Modified Mini-Mental State Examination. The most prevalent diseases were hypertension (60.8%), osteoarthritis (28.6%), coronary heart disease (16.6%), and diabetes mellitus (15.2%). Mean usual gait speed was 1.17 ± 0.24 m/s. No significant differences were found between Sample A and Sample B (all $P>.2$). Mean follow-up duration was 4.9 ± 0.9 years.

Event rates per 100 participant-years according to usual gait speed (for 0.05-m/s intervals) were calculated in a randomly selected subset (Sample A, n = 2,031; two-thirds of the overall participants) and are shown in Figure 1. By examining the graphical distribution of the crude event rates for persistent lower extremity limitation (Figure 1, Panel A), a cutpoint (1 m/s) defining risk levels was identified. Thus, two groups of participants were identified according to gait speed (high risk < 1 m/s; low risk ≥1 m/s). The identified cutpoint was then used for the secondary outcomes (Figure 1, Panel B). The trend between usual gait speed and risk of persistent lower extremity limitation was similar across sex and race groups.

Positive and negative likelihood ratios for primary and secondary outcomes according to specific usual-gait-speed cutpoints for Sample B are shown in Table 1. Results show estimates of the predictive value of cutpoints different from the one chosen and illustrate the continuous gradient of risk between usual gait speed and health-related outcomes.

The predictive value for major health-related events of the 1-m/s cutpoint chosen was then validated in Sample B

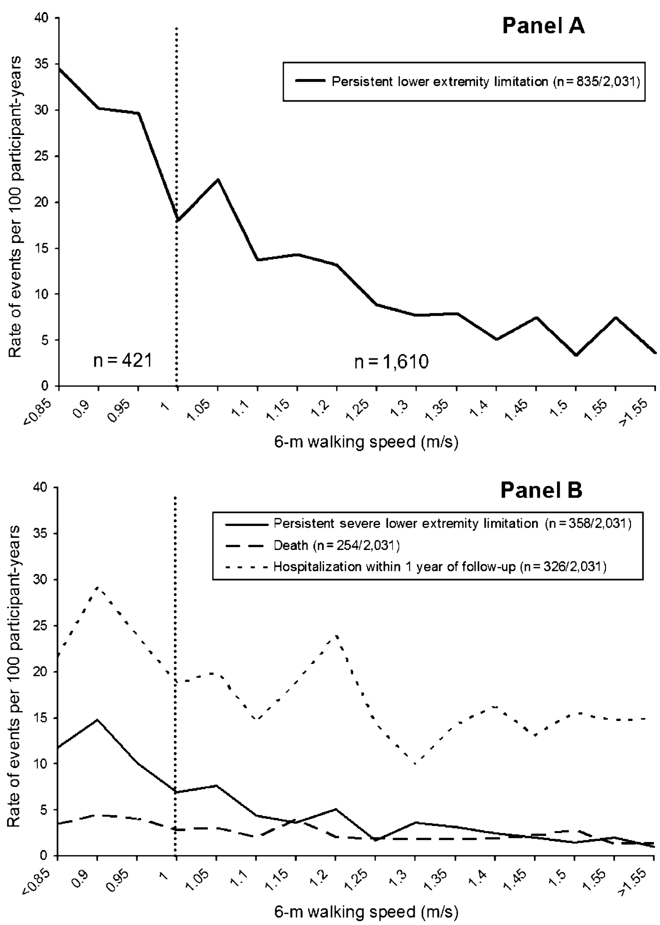

Figure 1. A. Rate of persistent lower extremity limitation events (primary outcome) per 100 participant-years according to 6-m walking speed (per 0.05-m/s increase). B. Rate of persistent severe lower extremity limitation, death, and hospitalization events (secondary outcomes) per 100 participant-years according to 6-m walking speed (per 0.05-m/s increase).

Table 1. Positive (+) and Negative (−) Likelihood Ratios for Primary and Secondary Outcomes According to Specific Usual Gait Speed Cutpoints in the Validation Group (Sample B; n = 1,016)

Gait Speed Cutpoint (m/s)	Persistent Lower Extremity Limitation		Persistent Severe Lower Extremity Limitation		Death		Hospitalization	
	+	−	+	−	+	−	+	−
	Likelihood Ratio (95% Confidence Interval)							
0.8	5.23 (2.63–10.40)	0.93 (0.90–0.96)	3.78 (2.18–6.56)	0.91 (0.86–0.96)	1.79 (0.95–3.38)	0.97 (0.92–1.01)	2.14 (1.17–3.91)	0.95 (0.91–1.00)
0.9	4.29 (2.87–6.40)	0.83 (0.79–0.88)	3.37 (2.42–4.69)	0.79 (0.72–0.87)	1.97 (1.36–2.85)	0.89 (0.83–0.97)	1.59 (1.07–2.35)	0.93 (0.87–1.00)
1.0	2.84 (2.25–3.60)	0.71 (0.65–0.77)	2.28 (1.84–2.82)	0.69 (0.60–0.79)	1.52 (1.19–1.95)	0.85 (0.76–0.96)	1.33 (1.03–1.73)	0.90 (0.81–1.00)
1.1	2.03 (1.74–2.37)	0.61 (0.54–0.69)	1.84 (1.59–2.13)	0.57 (0.47–0.69)	1.38 (1.16–1.65)	0.78 (0.66–0.92)	1.33 (1.12–1.59)	0.80 (0.69–0.94)
1.2	1.60 (1.44–1.78)	0.52 (0.44–0.61)	1.45 (1.30–1.61)	0.52 (0.40–0.68)	1.30 (1.16–1.47)	0.66 (0.52–0.84)	1.22 (1.07–1.38)	0.75 (0.60–0.93)
1.3	1.35 (1.25–1.46)	0.43 (0.34–0.55)	1.28 (1.18–1.38)	0.43 (0.29–0.62)	1.18 (1.09–1.29)	0.61 (0.44–0.85)	1.15 (1.05–1.26)	0.67 (0.49–0.92)

(Table 2). Participants with a walking speed of less than 1 m/s presented a significantly higher risk for all events than the reference group (participants with usual gait speed $\geq$1 m/s); high-risk participants had a greater risk of persistent lower extremity limitation (RR = 2.20, 95% CI = 1.76–2.74), persistent severe lower extremity limitation (RR = 2.29, 95% CI = 1.63–3.20), death (RR = 1.64, 95% CI = 1.14–2.37), and hospitalization within 1 year (RR = 1.48, 95% CI = 1.02–2.13) after adjustment for potential confounders identified in the univariate analyses. Results from adjusted Cox proportional hazards analyses stratified by sex and race were similar to the overall findings and are not discussed further. Small changes in the hazard ratios were seen for the mortality and hospitalization outcomes after adjustment for potential confounders. Physical activity, obesity, and education were the three strongest factors affecting estimates of the relationship between usual gait speed and persistent (severe) lower extremity limitation.

DISCUSSION

This study demonstrates the continuous relationship between usual gait speed over a short (6-m) course and subsequent risk of major health-related outcomes in relatively healthy older people. It identifies a cutpoint of 1 m/s as a clinically meaningful cutpoint, as suggested by the RRs and the positive and negative likelihood ratios.

The usual gait-speed cutpoint identified (1 m/s) corresponds to 6 seconds to complete the 6-m course. By providing the same cutpoint, independently of sex and race differences, the use of this measure in clinical settings has been simplified.

There may be important losses of information when continuous variables are categorized, but the use of a clinical cutpoint often enhances the adoption of the measurement. Moreover, the identified cutpoint for usual gait speed may also represent a target for interventions aimed at improving physical performance.

In the present study, the incidence of persistent lower extremity limitation was used as the primary outcome. This outcome is particularly important in clinical practice because it is predictive of severe health-related outcomes in older persons such as mortality and subsequent physical disability.[10–12,14] Even if mobility is only one of several types of physical disability, it is a major risk factor for difficulty and dependency in other domains of physical functioning,[14] causing decreased quality of life in older adults[14,18] and substantial social and healthcare needs.[19] Consequently, prevention or postponement of mobility disability represents a high priority.[20] Moreover, mobility disability tends to occur early in the disabling process[14] and is therefore amenable to interventions. Higher rate ratios were found for the identified cutpoint in the prediction of persistent (severe) lower extremity limitation than for those predicting hospitalization and mortality. This is likely a result of the close relationship between the self-reported walking limitation and the performance of the walking task. The absolute rates of hospitalization and death in the study participants are low because of the relatively healthy status of Health ABC participants. Nevertheless, the findings demonstrate that walking speed can predict hospitalization and death.[6,21,22] An explanation for the

Table 2. Rate Ratios (RRs) and Event Rates for Persistent (Severe) Lower Extremity Limitation, Hospitalization, and Mortality According to 6-M Walking Speed Cutpoint in the Validation Group (Sample B)

6-M Walking Speed, m/s	Events/Participants	Rate of Events Per 100 Participant-Years	RR (95% Confidence Interval) Unadjusted	Adjusted*
Persistent lower extremity limitation				
≥1.00	258/772	9.49	1 (Reference)	1 (Reference)
<1.00	163/244	28.45	2.84 (2.33–3.46)	2.20 (1.76–2.74)
Persistent severe lower extremity limitation				
≥1.00	99/772	3.14	1 (Reference)	1 (Reference)
<1.00	80/244	9.46	2.98 (2.22–4.01)	2.29 (1.63–3.20)
Death				
≥1.00	108/772	2.86	1 (Reference)	1 (Reference)
<1.00	55/244	4.80	1.70 (1.23–2.36)	1.64 (1.14–2.37)
Hospitalization				
≥1.00	117/772	16.39	1 (Reference)	1 (Reference)
<1.00	51/244	23.39	1.43 (1.03–1.98)	1.48 (1.02–2.13)

* Adjusted for age, sex, race, site, smoking, body mass index > 30, Modified Mini-Mental State Examination score < 85, physical activity level, diabetes mellitus, hypertension, and cerebrovascular disease.

predictive value for events apparently not related to lower extremity function can be found by considering usual gait speed as an indication of the extent of cumulative age-related body changes or of disease burden. RRs from unadjusted and adjusted models for mortality and hospitalization were found to be similar, suggesting that usual gait speed is related to these two outcomes independent of the presence of common medical conditions and disease risk factors.

Several physical performance tests have been shown to reliably predict major health-related events in older persons, but use of standardized measures in clinical settings is not widely practiced because of insufficient time, inadequate space, and the need for special equipment and training.[2] This study evaluates a physical performance measure that is quick to perform, does not require any special equipment, and can be easily administered by nonmedical personnel. These characteristics should allow this measure of gait to be implemented in clinical and research settings for more in-depth evaluation of older subjects. Moreover, it has been suggested that assessing gait speed alone has similar predictive value for disability as the full Established Populations for the Epidemiologic Study of the Elderly battery of performance tests.[9]

Several possible biological mechanisms may explain the link between low physical performance and negative health-related events. Inflammation, inversely associated with physical performance,[23] might play an important role in accelerating body composition changes that are typical of the aging process.[24] A significant relationship between low skeletal muscle mass, functional impairment, and disability has been demonstrated.[25] Moreover, obesity, another condition associated with inflammation, is strongly associated with disability, especially lower-body disability.[26] A significant loss in muscle strength has also been demonstrated in subjects with sarcopenia and sarcopenic obesity.[27]

The gait-speed cutpoint identified (1 m/s) is faster than those reported in other studies,[1,3,5,7,10,11] showing that a gradient in risk can be identified even at higher gait-speed levels in an initially healthy population, such as the Health ABC cohort. Several previous studies presented physical performance results based on shorter walk tests (e.g., 4-m[1,3,11] and 8-foot[5,6,9,10,22] walk tests), in which the effect of the acceleration from the initial stationary position may be a more influential component, reducing average speeds.

Some limitations of the current study need to be mentioned. It was not possible to explore the physiological mechanisms of the aging process at the basis of these findings. Therefore, gait speed may simply capture prognostic information that the other measures used (such as comorbidity) were not capturing. Moreover, the cutpoint validity was assessed in a subsample of the Health ABC cohort but not in a separate data set. Finally, the inclusion criteria of Health ABC, composed of well-functioning persons aged 70 to 79, may have limited the generalizability of the results.

In conclusion, the use of a simple measure of walking speed can improve the clinical evaluation of older persons, providing an earlier detection of individuals at higher risk of major health-related events. Because the presence of other common medical conditions does not strongly influence this risk, it adds to the tools available for clinical assessments. Older persons with gait speed slower than 1 m/s (equal to more than 6 seconds to walk 6 m) should be considered at high risk of adverse health outcomes. By providing a clinically useful cutpoint for a simple, quick, easy-to-perform test of physical function, it is hoped that the routine use of this simple gait speed assessment will be promoted and encouraged in clinical and research settings.

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